

Statistical Bibliography in the Health Sciences

BY L. MILES RAISIG, *Research Associate*

*Yale Medical Library
New Haven, Connecticut*

THE sustained interest in documentation, as a key to the retrieval of information in the literature of the sciences, has obscured largely the potential utility of statistical bibliography as a method of analyzing information needs. In the belief that a discussion of the latter may be of value to interested biomedical librarians and scientists, a review of investigative methods and results in the health sciences is offered here.

Statistical bibliography may be defined as the assembling and interpretation of statistics relating to books and periodicals; it may be used in a variety of situations for an almost unlimited number of measurements. Within the last forty years bibliographical statistics have been collected and explained in several fields of science for these main purposes: to demonstrate historical movements, to determine the national or universal research use of books and journals, and to ascertain in many local situations the general use of books and journals.

A pioneer example of the bibliographic study used to demonstrate historical movements is the statistical analysis of the literature of comparative anatomy from 1550 to 1860, reported in 1917 by Cole and Eales (1). In a textual discussion and a series of charts the authors illustrate clearly the fluctuations of interest and the distribution of the literature among countries within periods and by divisions of the animal kingdom, and give the sources from which their statistics were derived. This study stands as a statistical history of comparative anatomy; correlated with other data it may yield new meaning and offer new interpretations on the birth and death of interests in this field.

E. Wyndham Hulme, a former librarian of the British Patent Office and an enthusiastic proponent of the statistical illustration of the history of science, in 1922 offered the results of a long analysis of the journal entries in the seventeen sections of the English *International Catalogue of Scientific Literature* (2). In four tables Hulme indicated the following: the rank order of entries in physiology, bacteriology, serology, biology, and other subjects of interest in medicine; the rank order of the sciences based upon their output of periodical literature; the number of journals referred

to in the annual issues, arranged by subject; and the number of indexed journals arranged by countries.

These requisites for such universal demonstrative studies were suggested by Hulme: "(1) the statistics must be international in scope and sufficiently extended for the purpose in view; (2) original work must be distinguished from educational literature; (3) the statistician must possess a competent knowledge of his subject matter" (3). With the substitution of "national" for "international" these same requisites will serve for the investigations of movements in scientific fields within individual countries.

Of the three most common applications of statistical bibliography, the citation analysis of the research usage of periodicals has yielded the greatest number of published results and the greatest variety of interpretations.

In 1927 Gross and Gross, while attempting to compile a list of journals indispensable in chemical education, gave the scientific world their method of counting and analyzing the citations appended to periodical articles (4). Their argument, that such an investigation into the library tools of the scientists contributing to progress in chemistry would prove fruitful, was based on these assumptions: the usage given a scientific periodical in any field may be measured by the number of times it is cited in the literature of the field; the journal chosen as a source is representative of all of the journals of the field. Later users of the Gross and Gross method added these assumptions: any subjectively popular and much-used journal may be chosen as the source of citations; if two or more journals are used as sources, either or all may be weighted equally.

It is not an exaggeration to state that a whole generation of librarians and scientists has been trapped statistically and semantically in the assumptions and methods of the Gross and Gross type investigation. The discussion and review which follow will show that, in spite of the appearance of a number of citation analyses, the rich potential of this bibliographic device has never been realized.

The citation analysis, however used in whatever location, remains a statistical exercise and must satisfy basic statistical requirements. The Gross and Gross assumption that a single journal may be representative of a field appears wholly indefensible in the light of even the most elementary knowledge of statistical theory and practice. The assumption denies the validity of the random sample, and is false.

Equally indefensible and false is the assumption that any subjectively popular, esteemed, or much-used periodical may serve as the single source for the analysis. This assumption not only denies valid sampling methods, but openly injects subjective choice as an aid into the investigation. The

implication that the references appended to the articles in the subjectively popular journal are more carefully compiled and greater in number, and therefore a more valuable source than the references in a less popular journal, is itself subjective and unproven.

The choice of one "best" medical periodical to represent our citation population is analogous to selecting one "best" fraternity as representative of a collegiate undergraduate population. As Clark (1953) states in his statistical text, the members of one fraternity are not representative of all of the students of a college, and do not constitute a random sample (19). Nor, in like manner, are the citations contained in one or more issues or volumes of *Journal of the American Medical Association* (a commonly used "best" source) either representative or a random sample of those to be found generally in American medical periodicals.

The importance of the random sample in the citation analysis cannot be overstressed. Wallis and Roberts (1956), in discussing the sample in their text on statistics, state that certain patterns of variability or dispersion are revealed in the study of samples (groups) of various populations (people, things, events); these patterns can be interpreted through the laws of mathematical probability, and objective generalizations can be made from the samples to the populations (21). The pattern of any sample can be interpreted and the objective generalization made *only if the sample is random, for the laws of probability will not apply otherwise*. Our test of randomness in the citation analysis is simple: has every citation in the population an equal chance to be chosen and counted? If it does not, randomness is not secured, inferences suggested are without foundation, and generalizations made to the whole population are neither objective nor valid.

The choice of several journals as analytic sources, and their equal weighting, are meaningless steps unless and until the sampling procedure is fairly done. If we are to study successfully the great number of health science periodicals currently available, we must examine with care as many of them as possible. If we are to investigate and interpret the characteristics of citations in these periodicals, then a pool of all of the citations appearing in them comprises our source. Since it would be impracticable and very costly to examine and record every citation in a given unit of issue of each available periodical, we turn to the random sample for assistance. With this device every citation in every periodical available for study has an equal chance of being analyzed; the interval of citations chosen for examination (every twenty-fifth or fiftieth or hundredth, etc.) can be determined scientifically within accepted statistical practice.

Too little attention has been paid to defining or limiting those publications which may be used as reference sources. In the citation itself there

is found a concrete standard of definition. The late John F. Fulton, in an address in 1933 to degree candidates of the Department of Physiology, Yale University School of Medicine, characterized the citation as an important element in the writer's chain of logic (8). Each reference may be considered in a larger sense to be a link in the great chain of logic recorded in every field of intellectual activity. We need not be concerned here that the authors of scientific papers are cautioned to cite to avoid plagiarism, or are advised not to cite merely to give credit or to reaffirm commonly accepted truths. We expect the citation to support the author's claim or belief or thesis, and in analyzing the stream of logic revealed in citations we can secure significant data on the research use of scientific periodicals.

It is axiomatic that there may serve as analytic sources only those publications in which the citations demonstrate usage within the stream of logic. It must be apparent that mere masses of citations, no matter how convenient, are worthless and misleading. If we are to investigate the research use of periodicals, we may not measure such use with citations gathered for other purposes. This immediately excludes the annual review and the collection of unattached references as analytic sources.

The annual review, or yearbook, or regular and progressive summary or digest of periodical and other publications in a field of science, serves to bring to the reader in greatly reduced form all that is significant in a period of time. A typical description of this purpose is most succinctly given in the 1961 issue of *Annual Review of Physiology*: "The Review . . . will continue . . . to sift the excellent from the merely good, to recognize and evaluate new trends in physiological thought, to warn against blind fashion. . . ." (25).

In the preparation of the digest its reviewers select the "excellent" and reject the "mediocre" and the "poor." These choices are obviously subjective and prejudiced, and the use of the digest as a citation source creates for the investigator a leaning which no amount of weighting can negate. The digest's citations are appended as signposts to the articles selected for review, so that the interested reader may find the originals. The chains of logic which have been forged by hundreds of authors are irrevocably destroyed in gathering the "significant." These review citations do not represent research use by authors, and their convenience offers only confusion in the study of citation characteristics to be found in the continuity of logical relationships. The review is not without a logic of its own, but it cannot take the place of original articles in the analysis.

The published or unpublished collection of uncritical subject references compiled by the librarian, and typified as a "subject bibliography," is equally without value as a citation source. The collection is much like the

annual review in being a gathering of "significant" or "best" material, with all the subjectivity that such choices must carry.

In the collections of critical references provided by one or more authors of a book, the investigator may possibly find the logical setting of citations so necessary in his source. Those appended citations, however, which are not related by symbols or obvious connection to the text may be rejected because no apparent logical continuity has been demonstrated. So may the appended exhaustive bibliography be an unwise choice, since it serves as an inclusive informational guide not directly concerned with our chain of logic. Regardless of how excellent or popular the book appears, its employment as a sole source of citations is as indefensible as the like use of one periodical.

The most suitable sources for the citation analysis of the use of periodicals are, by reason of their variety, frequency, number, currency, and inclusion of citations related in logic, these same periodicals. In the process of recording the characteristics of the citations chosen, we amass the sums of references to articles in individual periodicals. In all but one of the studies in the Gross and Gross tradition considered here, these sums have been used to determine the rank orders of the periodicals cited without further processing to equate any differences in frequency of the latter. Thus, the citations of the quarterly which may publish 40 original articles each calendar year have been casually mixed with those of the monthly publishing some 120 articles and those of the weekly publishing 240 articles in the same time period. Yet it must be apparent that if the usage of the quarterly is to be measured fairly against the monthly and the weekly with their many more articles, some adjustment must be made in our raw sums to relate the numbers of articles cited to the numbers of articles actually published and available for citing.

An arbitrary and incorrect solution would be to weight the total sums of citations secured to agree with the frequency of each periodical cited. The fallacious argument is made that since the monthly publishes in one year three times as many issues as the quarterly, multiplying the sum of the citations to the latter by three would create a parity of measurement. So would the quarterly's citation sum require multiplication by 13 to bring it into parity with the weekly's sum. Our measurement, however, is concerned not with the periodical unit of issue, but with all of the articles cited and published within the unit.

It follows that replicate citations to the same articles can be discarded (unless we propose to measure the use or popularity of individual articles), and one citation only need be counted for each. When the total of single citations within each periodical under investigation is reached, there is computed for each periodical the relationship between the number of

articles published in it and the number of articles cited. The index of use of all articles in the unit of measure is derived from the formula:

$$\frac{\text{number of articles subsequently cited}}{\text{number of articles originally published}} \times 1000.$$

This measure of "research potential realized" requires neither weighting nor refinement; differences in the numbers of articles published in several periodicals are adjusted logically to overcome any advantage of frequency.

Counts of articles published can be secured in the direct examination of periodicals, and for the period 1950-59 from the "Register of Articles" in the now defunct *Current List of Medical Literature* of the National Library of Medicine. The Register offers an accurate series of the articles indexed in the *List*, numbered and arranged in periodical units. When used with the random sampling of citations, the Register's contents can yield quick counts for the determination of indexes of use.

It is distressing to report that of the twelve citation analyses briefly reviewed in the accompanying table, *only one* approaches the validity we require. Casey was much concerned with objectivity in the selection of citation sources and in the size of the sample taken (15). His arbitrary method of selection approximated true randomness, and, except in his first choice, reduced subjectivity to a minimum. In attempting to measure the influence of North American and British journals on medical progress in the United States and Great Britain, he found that the influence exerted (based on references secured in 1934) "could have been good, bad, or indifferent," and that American state medical periodicals exerted little direct influence (16).

Although all other studies reviewed fail in one or more ways to attain validity, they contain certain indications of interest which might well be reinvestigated with profit. Sherwood in 1932 reported German to be the most valuable foreign language for the American physician (6); Jenkins remarked in the same year that few Americans read foreign languages easily, and found desirable therefore the fact that of 38 journals ranked in his study 37 were in English (7).

Jenkins (7) and Brodman (17) apparently assumed that their individual opinion polls, each limited to the personnel in one group or department, were adequate and representative of the opinions of the many scientific writers everywhere who were contributing to the periodicals which they studied; the lack of the random sample in each study leaves the assumption without foundation and the resultant data of no value in making inferences. Further, Brodman's use of the results of her poll as a standard to test the Gross and Gross basic assumptions was quite futile; her poll meas-

TABLE 1
CITATION ANALYSES OF HEALTH SCIENCES PERIODICALS, 1931-57

Investigator	Year	Subject	Area of Usage	Sources	Features	Statistical Characteristics
Jenkins (5)	1931	General medicine	USA British Empire German language	J.A.M.A. Brit. Med. J. Klin. Wschr.	Ranked lists; weighted "international scale"	Sources not representative or adequate; sample not randomly chosen
Sherwood (6)	1932	General medicine and specialties	USA	J.A.M.A.	Ranked lists; short list of books, etc.	Source not representative or adequate; sample not randomly chosen
Jenkins (7)	1932	Child guidance	USA	Abstracts; opinion poll; current col- lected bibliog- raphies	Ranked lists; tabular representation of fields	Sources not representative or adequate; sam- ple not randomly chosen; opinion poll as measure of undifferentiated total use inap- propriate as standard of citation use only
Mengert (9)	1934	Endocrinology of sex	USA	21 contributors' bib- liographies in 1 textbook	Ranked lists; graph of diminishing returns in citations	Sources not representative or adequate; sample not randomly chosen
Gregory (10)	1935	Endocrinology	USA	Librarian's bibliog- raphies; textbook; Mengert's results	Ranked list; tabular comparison with 3 earlier studies	Sources not representative or adequate; sample not randomly chosen
Hackh (11)	1936	Dentistry	USA	Periodicals	Ranked lists; table of source periodicals	Representation and adequacy questionable of sources subjectively chosen; sample not randomly chosen
Gregory (13)	1937	General medicine and 27 subjects	USA	Periodicals; text- books	Ranked general and subject lists	Sources not representative or adequate; sample not randomly chosen
Henkle (14)	1938	Biochemistry	USA	5 volumes of Ann. Rev. Biochem.	Ranked lists; correla- tions offered for re- liability of sample	Source not representative or adequate; sam- ple not randomly chosen; reliability of sample unproven against any standard

Casey (15)	1942	General medicine in English language	USA Great Britain	75 periodicals in English language	Ranked list based on 1934 data; reliable, adequate, objective sample offered	Objectivity in selecting first sources and true randomness in sample not secured, but study most nearly approaches validity in its sampling, procedure and interpretation
Brodman (17)	1944	Physiology	USA Great Britain German language	3 periodicals; Ann. Rev. Physiol.; opinion poll	Ranked lists; correlations attempted to test Gross and Gross assumptions	Sources not representative or adequate; sample not randomly chosen; opinion poll as measure of undifferentiated usefulness inappropriate as standard of citation use only
Brown (20)	1956	Physiology	USA	7 periodicals	Ranked list based on 1954 data as part of study of several subject fields	Sources not representative or adequate; sample not randomly chosen
Morgan (22)	1957	Physiology	USA Canada	7 volumes of Ann. Rev. Physiol.	Ranked lists; correlations offered for reliability of sample	Source not representative or adequate; sample not randomly chosen; reliability of sample unproven against any standard

RELATED STATISTICAL STUDIES, 1937-60

Hunt (12)	1937	General biomedicine	Univ. Chicago Bio-Medical Libraries	Circulation records	Ranked lists; comparison with Jenkins and Sherwood studies	Valuable as study of undifferentiated "home use"; results inappropriate as standard to measure citation use only
Postell (18)	1946	Physiology	Louisiana State Univ. Med. Library	Circulation records	Ranked list; correlated to Brodman study of Gross and Gross	Applied part of lengthy undifferentiated total use study; results inappropriate as standard to measure citation use only
Raisig (24)	1960	Chemistry	USA	5 highest ranked periodicals in Gross and Gross study	New ranked list of 5 periodicals in publication-citation relationship	Discussion of raw data weakness in citation analyses, and demonstration of corrective method based on numbers of articles published and articles cited

ured the "value" or undifferentiated total usefulness of periodicals, while the Gross and Gross method was concerned only with the citation use.

Henkle (14) and Morgan (22) interpreted the coefficients of correlation which they found for their annual review sources to mean that the sources were adequate and representative and covered well the literatures of their subject fields. Neither investigator measured his source against any standard of coverage. I prefer to interpret the respective coefficients resulting as indicative that from year to year about the same number of annual reviewers culled about the same numbers of articles from about the same periodicals, that this occurred as a result of annual review policy or of the coincidental location of reviewers and convenience of periodicals for review, and that the sources are neither adequate nor representative.

In the lists of ranked periodicals in subject fields assembled by Mengert (9), Gregory (10), and Morgan (22), I note that the specialized periodical for the field under study was not necessarily ranked first. In Gregory's (1935) study of periodicals in endocrinology, *American Journal of Physiology* was ranked first, *Comptes rendus de la Société de biologie*, second, and *Endocrinology*, third. In the calendar year 1932 the first journal published 278 original articles, the second published some 1,500 such articles, and the third published 62. The computation of the publication-citation index of use for each of these journals might well secure for *Endocrinology* the first place we would expect it to assume in its field.

Several investigators have remarked on the large proportion of references to a few highest ranked periodicals, and on the concentration of references within the ten year period immediately preceding the years of analysis. Also found was the wide scattering of citations among the lower ranked journals. Sherwood found that books were cited one tenth as frequently as periodicals, and bulletins, reports, and transactions were cited one twentieth as frequently (6). There was noted in Hackh's survey of dental periodicals the very great variety of periodicals cited (11).

The single remaining copy of Hackh's unpublished table of source periodicals apparently exists only in the archives of the Medical Library Association. It was unfortunately not available during the preparation of this review. However, from Hackh's own description of the choice of his sources, there can be no doubt of their inadequacy.

Hunt's (12) report on the recorded home use circulation of journals in the Bio-Medical Libraries, University of Chicago, offered a comparison of the outstanding differences in the periodical rankings of the Jenkins (5), Sherwood (6), and Hunt studies. Hunt attempted to explain these differences by stating that the investigations covered different years, and that the change in content of certain German journals would likely alter their rankings. Essentially, Hunt's circulation data measured undifferentiated use, and could not therefore serve as a standard to measure the citation (research) use only as attempted by Jenkins and Sherwood.

A similar application by Postell of Louisiana State University Medical Library circulation data could not objectively support Brodman's judgment that the Gross and Gross method was unreliable (18). As in Hunt's study, the standard or gauge of unspecialized general use may not serve to measure a specific use.

In my 1960 study there was demonstrated the raw data weakness of the Gross and Gross method, and the relationship of the cited and published articles under analysis (24). The revised rankings found here for the first five periodicals of the original Gross and Gross study are not valid for practical use; the citation counts which established their ranks in both studies came from one inadequate source periodical only.

There has grown with the use of the Gross and Gross method a semantic confusion concerning the generalizations which the citation analysis might yield from its measurements. This has likely caused many serious investigators to condemn the analysis without trial to nonuse and oblivion. Such disapproval is doubly unfortunate, for it fastens upon a sound mathematical method all of the weaknesses of the Gross and Gross assumptions, and frustrates the development and use of a device for which there is no substitute.

The confusion has centered in the statements or claims or inferences that the citation analysis could or would evaluate (6, 13, 14, 15, 22, 24) or assess the quality (11) of the periodical literature of a subject field, or that it could or would reveal leading (5, 6), essential (13) periodicals of importance (5, 7, 10, 12, 13, 14) carrying noteworthy advances (6).

I believe that any inferential interpretation of analytic data concerning the use of health sciences periodicals must await the reporting of a statistically sound analysis. At that time our generalizations might be this: since the indexes of realized research potential of certain periodicals are higher, these same periodicals appear to have greater interest, timeliness, or popularity, but not necessarily greater merit, than those periodicals with lower indexes in the period under study. Or, if we are analyzing the use of non-periodical literature not requiring the computation of indexes of realized research potential, we might infer that these books, reports, etc., are more cited, and therefore appear to have greater interest, etc.

The nonstatistical disapproval summarized by Voigt (1959) charged that the citation analysis cannot measure the use of current literature, fails to distinguish references of primary and lesser importance, and does not provide information on materials read but not used in the research process (23). The first criticism will remain true only until an enterprising researcher samples the references appended to manuscripts awaiting publication in periodical editorial offices. He can then provide information on the use of this literature at the time or even before it becomes current. The weakness here has been in poverty of investigative imagination and not in lack of method.

To demand that the analysis should separate references for their value is to require that the method should bestow omniscience upon the analyst. It must be repeated that the analysis is a statistical exercise, and that it will not and cannot measure that which is nonexistent or not available at least for sampling. The defect lies not in the device, but rather in the failure of the scientist-citer to communicate to the reader the relative significance of his references. I suggest that the way is clearly open for the expression of reference values, and that this must come from the writer.

It seems likely that editorial policy concerning space limitations in periodicals would forbid the publication of citations of the literature which in the preparation of a paper had been read and rejected. Any information on such research wastage must also come from the writer. A closely controlled circulation-questionnaire study, sampling the manuscript yield of several scientists, would probably provide clues or indications of interest and value. To reject the citation analysis because it alone cannot give such data is to fail to appreciate its potential and limitations.

For any citation analysis with claim to objectivity and validity, I offer these essentials useful both as procedure and as standard to gauge the success of the study: (1) acknowledgment of unavoidable subjectivity in the choice of sources; (2) supporting proof that the sample of the population is as typical or as representative as claimed; (3) description or demonstration of the method of sampling (wholly random, stratified, or other); (4) authority or basis for assumptions made; (5) inferences, conclusions, and interpretations consistent with purpose, method, and results.

With these essentials what results may we seek? We wish to find primarily these characteristics for cited periodical articles and their sources in the health sciences: country of origin, language and year of publication, and subject or specialty. To aid in ranking cited periodicals we wish to compute their mathematical indexes of use. If our analysis concerns the frequency of citations of books, dissertations, reports, transactions, annual reviews, and separate monographs, there are needed for each citation and its source these facts: country, language, year, subject or specialty. The patterns of citing habits of authors, and knowledge of their affiliations and educational backgrounds, might also be of value.

The measurements revealed may be interpreted to determine obsolescence rates in serials and nonserials, and to reach decisions to build or create a better balance in library holdings, to destroy, shift or store older and lesser used materials, to choose literature to index and abstract, and to plan co-operative library enterprises to extend or enlarge service to the reader.

We look to the citation analysis for measurements of usage, and leave to the scientist-citer any judgments on his literature. In statistical bibliography we hope to find new ways to determine information needs in the health sciences.

I am indebted to Frederick G. Kilgour, Librarian, Yale Medical Library, and to Dr. Colin White, Biometrician, Department of Epidemiology and Public Health, Yale University School of Medicine, for many valuable suggestions; the latter's *Sampling in Medical Research*, Brit. Med. J. 2: 1284-1288, Dec. 12, 1953, has been especially helpful.

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